Hydrogen Peroxide Oxidant Fuel Cell Systems for Ultra-Portable Applications

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Introduction

Miniature fuel cells, based on direct methanol fuel cell technology (DMFC), that can fit the "form factor" of batteries for portable electronics have been developed [1-5]. The architecture of these fuel cells is based on metal-air batteries such as the Zinc-Air battery, which is used in hearing aids and cellular phones. There are two major issues in adapting DMFC technology to function in a metal-air architecture, reactant supply and product containment. Miniature fuel cells rely on receiving their oxidant from the air, thus placing a constraint on the operating environment for the electronics that use these power sources. Matting a miniature fuel cell with an oxidant such as hydrogen peroxide can extend the operational environment of portable electronics to locations where the free convection of air is limited.

This paper will address the issues of using hydrogen peroxide as an oxidant fuel in a miniature DMFC system. Cell performance for DMFC based fuel cells operating on hydrogen peroxide will be presented and discussed.

Results and Discussion

When hydrogen peroxide is introduced to the cathode compartment of a direct methanol fuel cell it is decomposed to oxygen at the surface of the electrode backing and at the catalyst/ electrode-backing interface. The freed oxygen can then take place in the cathodic reaction for the oxidation of methanol in the DMFC. The fuel cell reaction is as follows:

Anode: $CH_3OH + H_2O \rightarrow 6H^+ + 6e^- + CO_2$ (1)

Cathode: $3H_2O_2 + 6H^+ + 6e^- \rightarrow 6H_2O$ (2)

Cell: $CH_3OH + 3H_2O_2 \rightarrow CO_2 + 5H_2O$ (3)

The polarization of a DMFC cell with an active area of 25 cm^2 operating on 3% hydrogen peroxide solution and 1M methanol at 22, 31, and 42 °C is shown in Figure 1. A 20 mA/cm^2 improvement in current density can be achieved when the operating temperature of cell is increased from 22 to 42 °C at a cell potential of 0.4 V. A plot of the calculated power density vs. applied current density for this cell is shown as Figure 2. This DMFC is capable of room temperature operation at a power density greater than 16 mW/cm^2 under an applied load of 64 mA/cm^2. The peak power for this cell is 23.6 mW/cm^2 at 42 °C under an applied load of 80 mA/cm2.

DMFCs operating on pure oxygen operate at about three times the power level shown in figure 2. As the concentration of hydrogen peroxide is increased, the power output of the cell also increases. The decomposition rate of hydrogen peroxide increases with increased concentration, thus the challenge is in delivering only the required stoichiometric feed of oxidant to the cathode electrode surface. Hydrogen peroxide is the controlling fuel in determining the energy density of a hydrogen peroxide/ DMFC fuel cell. Concentrations of 50 - 70% hydrogen peroxide will be required to realize system energy densities better than 50 Whr/kg.

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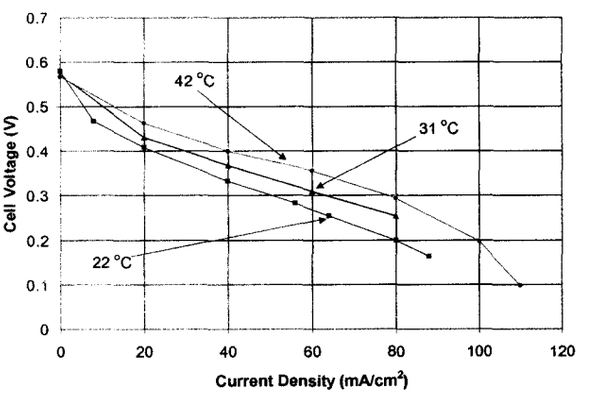

Figure 1. Current-Voltage characterization data collected for a hydrogen peroxide-methanol fuel cell operating at three different temperatures. Cell operation on 1M methanol and 3% hydrogen peroxide solution.

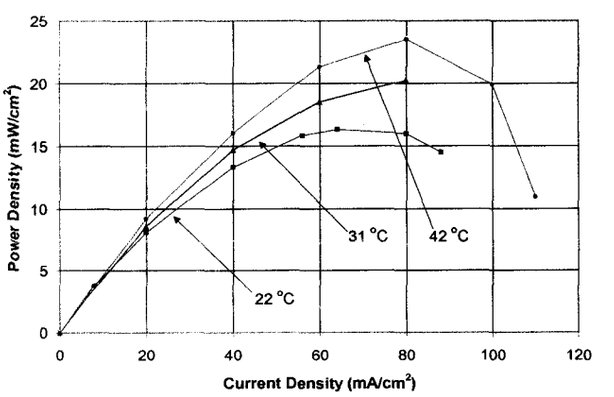

Figure 2. Calculated power density as a function of applied current density for a hydrogen peroxide-methanol